

Aging Conductor & Equipment

Analysis & Recommendations



RUS
2006 Electric Engineering Seminar

February 15, 2006
ORLANDO, FLORIDA

Presenter



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Problem



Part of your system is growing at a fast pace (>5% per year) -- ie, the suburban or urban part or along the interstate.

And part of your system is old and growing very slowly, if at all -- ie, the rural areas.

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What do you do?



Spend all funds on the growing part and
don't spend any money on the other part
until it falls down?

Don't spend any money at all ?
(are you an accountant?)

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What do you do?



Nothing?

Absolutely NOT!

Try to balance your expenditures across all
of your system to maintain a high degree of
reliable service and improve bad areas.

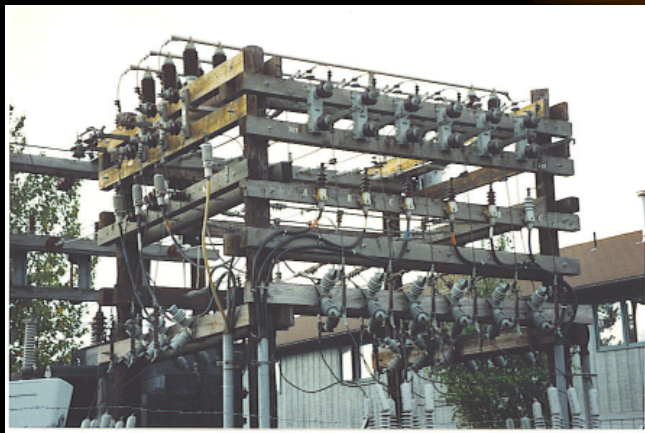
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The “Problem” (some of them)

- Old Poles
- Old & Obsolete Conductors (copperweld & aluminum)
 - Excessively long spans & aging conductors
- Bad right-of-way (extreme tree growth)
- Old & Obsolete Substations
- Old & Obsolete Substation Transformers
- Old Transmission Lines (34.5 kV, 46 kV)
- Old Recloser & Old Switches
- Old Voltage Regulators

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Wooden Substation



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Overloaded Substation



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Antique Substation – 1930's



Slide # 10

Antique Substation



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The “Problem” (some of them)

- Excessive outages on parts of the system
- Excessive animal-caused outages
- Excessive losses
- Inadequate budget
- PCB transformers
- Old concentric neutral underground
- Impending Liability

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The “Problem” (some of them)

- Inadequate sectionalizing and overcurrent protection
- Inadequate system detail maps
- Old knife blade switches
- Old reclosers
- Old ABS out of adjustment
- Insufficient grounding

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The “Problem” (some of them)

- Rusting equipment
- High voltage complaints
- Low voltage complaints
- No easement documentation
- Inadequate patrolling of lines
- Inadequate inspection of lines

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The “Problem” (some of them)

- Lack of records by specific areas or by specific districts
- Current records are probably system-wide or averages
- Some records exist by substation, but usually not enough

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The “Problem” (some of them)

- Antique SCADA system
- Antique two-way radios
- Antique microwave systems

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The “Problem” (some of them)

Keep in mind that most of rural America was electrified from 1945 to 1952 during the Truman Administration and a LOT of original line is still in the air.

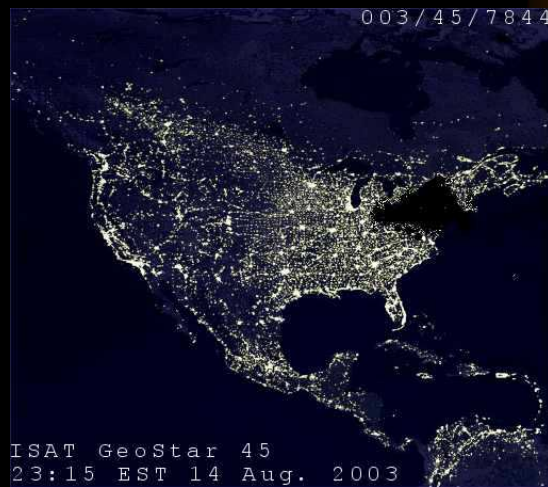
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Record Keeping Requirements (NEW)

- Do you currently keep outage records by substation, by circuit, by section — or by individual consumer?
- If not, start keeping them at least by substation and by circuit.
- Identify and quantify problems on a much smaller scale such as substation area than system-wide.

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Satellite Photo of Power Outage



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What Is Your Outage Criteria?

2 days / consumer per year?
5 hours / consumer per year?
1 hour / consumer per year?
Other?

Do you have different outage criteria for different parts of your system? Urban vs Suburban vs Rural?

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System Losses



- Do you currently keep system losses by substation on a monthly and yearly basis?
- Start keeping records on a much smaller scale (ie, by substation area) so you can identify problems in different parts of the system.

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System Losses



kWH losses are a costly part of System Operation.

They also present an opportunity to improve losses and reduce overall costs.

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Typical Systems



44,000 Consumers

kWH Purchased = 1,004,892,872

kWH Sold = 942,662,979

kWH Losses = 62,229,893 \Rightarrow 6.19%

Total Electric Revenue = \$64,148,728

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Typical Systems



Cost of kWH Purchases = $\frac{\$46,804,256}{1,004,892,872}$ = 4.658 ¢ / kWH

Cost of Losses = (62,229,893) (4.658 ¢ / kWH) = \$2,898,442

If you can lower losses 1%, you save \$468,246 !

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System Losses



One way to determine if you have excessive losses from your transformers is to compare installed transformer capacity to System Demand.

$$\frac{\text{Total Transformer Capacity (kVA)}}{\text{System Peak Demand (kW) / p.f.}} = \text{Over Capacity Factor}$$

If “Over Capacity Factor” is excessive (i.e., approaches 2.0), you are contributing to your losses!

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Underground Cable



- Do you have any High Molecular Weight (HMW) cable left? If so, replace it now!
- Have you identified all the areas where you have bare concentric neutral cable still installed? Non-tree retardant cable installed? What is the age of these respective cable installations?
- Have you quantified the replacement costs?
- Do you have a timeframe for replacement?

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Underground Cable



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Underground Cable



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Old Transformers



- Do you have any old 1.5 kVA, 3 kVA, 5 kVA, or possibly any 7.5 kVA transformers left? Check your CPR or mapping records.
- Do you have any PCB transformers or capacitors or substation transformers left?
- Put these on the list for possible replacement / retirement after checking the KWH usage, etc.

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Right-Of-Way



1. How many miles of right-of-way (ROW) do you have on your system that need to be cleared periodically?
2. Is the ROW in worse condition in the slow-growth areas?
3. How many miles did you clear, cut or mow last year?
4. How many years will it take, based upon past performance, to get over your system?

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Right-Of-Way ?



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Right-Of-Way

5. Since trees and bushes grow at different rates, what do you think your optimum cycle is?

5 years?
7 years?
10 years?
Longer?

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Recloser Maintenance

1. How many 1-phase oil circuit reclosers do you have on your system at present?
2. Do you check the operations counters on these devices from time to time? Do you maintain these devices?
3. Do you have a formalized maintenance plan, or is it the "Mother Nature Maintenance" Plan (as in, when it blows off the pole, you replace it with a new one)?
4. When is the last time you had a complete sectionalizing study performed by a consulting engineer or in-house?
5. One problem is that over time the available fault current exceeds the reclosers rating.

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1-Phase, Recloser Ratings

Recloser Size & Type	Interrupting Rating (Amps)	Operations before Recommended Maintenance
25H	625	100
35H	875	100
50H	1,250	100
25-4H	1,000	68
35-4H	1,400	68

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Recloser / Breaker Maintenance

When have you tested / calibrated your electro-mechanical relays? 1 year? 5 years? Ever?

CO-9, CO-8, IAC-53s?

Do you have plans to replace them?

Still have any Cooper/McGraw Edison Form 3A controls?

What about the contacts in the oil insulated units?

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Voltage Regulators

1. Do you check the operations counter monthly?
2. Has the number of operations exceeded manufacturers recommendations, typically 20 years or 1,000,000 operations (see manufacturers recommendations)?
3. Can the regulator stand the available fault current if a fault occurs? In general, this is 40 times the nameplate ampere rating of the regulator for a time period of 0.8 seconds.

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Pad Mounted Equipment

Transformers & Switchgear



1. Structural problems are the predominant failure mode.
2. Rust and corrosion are this type of equipment's biggest enemy.
3. Oil leaks can also occur.
4. Routine visual inspection is required (see CRN Report #98-11).

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Aging Conductors



Given the fact that Overhead Power Conductors have an average life span expectancy of 50-to-70 years, it is clear that many (if not all) of the original distribution lines have reached, will reach, or are beyond their useful life span.

See CRN Report #00-31

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Commonly Used Original Conductors

Size	Type	Approx Capacity	Rated Breaking Load (lbs) NEW Conductor	Weight (lbs/mile)
2A	Copperweld-Copper	240	5,876	1,356
4A	Copperweld-Copper	180	3,398	853
6A	Copperweld-Cooper	140	2,585	536
8A	Copperweld-Copper	100	2,233	392
9-1/2 D	Copperweld-Copper	65	1,743	298
3 #12	Copperweld	90	2,236	289
4	ACSR 7/1	140	2,288	356
2	ACSR 7/1	180	3,525	566
1/0	ACSR	230	4,280	769

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Why Conductors Fail

- Ice loading exceeds “maximum conductor tension”
- Long spans with ice loading
- Arcing damage (trees, lightning, wind, etc)
- Surface corrosion on copperweld conductors
- Electrolytic corrosion due to galvanic action

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Why Conductors Fail



- Surface corrosion and inner corrosion on aluminum conductors
- Loss of zinc coating on steel core wires (ACSR conductors)
- Fatigue failure due to wind-induced vibration
- Annealing due to excessive electrical current (hard drawn copper wire)

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Record Keeping On Conductors



Keep detailed outage records when conductor failure is the cause.

A database needs to be built and maintained detailing conductor failure.

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Inspection Provisions



The inspection provisions are contained in the 2002 NESC, Section 214, Page 60 as follows:

A. When In Service:

1. Initial Compliance with Rules: lines and equipment shall comply with these safety rules when placed in service.
2. Inspection: lines and equipment shall be inspected at such intervals as experience has shown to be necessary.
NOTE: It is recognized that inspections may be performed in a separate operation or while performing other duties, as desired.

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Inspection Provisions



A. When In Service (continued):

3. Tests: when considered necessary, lines and equipment shall be subjected to practical tests to determine required maintenance.
4. Record Of Defects: any defects affecting compliance with this code revealed by inspection or tests, if not promptly corrected, shall be recorded; such records shall be maintained until the defects are corrected.
5. Remedying Defects: lines and equipment with recorded defects that could reasonably be expected to endanger life or property shall be promptly repaired, disconnected or isolated.

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Inspection Provisions

B. When In Service (continued):

1. Lines Infrequently Used: lines and equipment infrequently used shall be inspected or tested as necessary before being placed into service.
2. Lines Temporarily Out Of Service: lines and equipment temporarily out of service shall be maintained in a safe condition.
3. Lines Permanently Abandoned: lines and equipment permanently abandoned shall be removed or maintained in a safe condition.

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Line Inspection ?



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Deer Problems



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Deer Problems



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CATV – Inspection!



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Wood Pole with CATV Attachment



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Line By Apartment Bldg Horizontal Clearance ?



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Line Inspection



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Underground Utility Inspection



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RUS Bulletin 1730-1

Electric System Operation & Maintenance (O&M) says
in Section 3—Distribution Lines, Overhead (pg.8)

“... All overhead lines (including those on private right-of-way)
patrolled annually (walking, riding or aerial); more frequently
if experience dictates.”

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Webster's Collegiate Dictionary

The 9th Edition says:

Inspect:

1. To view closely in critical appraisal: look over
2. To examine officially

Patrol:

- a. The action of traversing a district or beat or of going the rounds along a chain of guards for observation or the maintenance of security
- b. The person performing such an action

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Line Patrol Plane



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Line Inspection ?



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Line Patrol ?



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Line Patrol & Inspection ?



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Line Inspection / Patrol



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Voltage Drop

- Does part of your system suffer from excessive voltage drop at peak times? This is another symptom of small conductor and long feeders.
- Keep in mind that the original REA designs used 40- to 60-kWH per consumer per month as their design criteria.
- The following are some of the constraints of small original conductor.

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Voltage Drop Table

Maximum Ampacity	Conductor	R+ ; x*	Single Phase Voltage Drop Factor @ 7.2 kV
?	#6 Steel	Who Cares?	Too Much!
90 A	3 #12	7.62+ j1.71	19.6
85	9-1/5 D	5.15+ j1.61	13.6
100	#8 A	3.72+ j1.54	10.3
140 A	# 6 CU	2.47+ j1.46	7.36
180 A	# 4 CU	1.64+ j1.47	5.45

* Ohms per phase per mile of line

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Voltage Drop Calculation

$$VD = \text{Voltage Drop} = \frac{(kW)(s)(VDF)}{1000}$$

= voltage drop on 120V base at 90% power factor

EXAMPLE:

$$VD = (300 \text{ kW})(5)(10.3) / 1000 = 15.45 \text{ V}$$

300 kW at the end of 5 miles

1-phase, 8A conductor

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Model Discrepancies

1. Line sections are of wrong distance.
Database build error.
2. Mixed conductor spans wind up on the database as largest conductor (ie, 1 #6, 1 #8, 1 #4, with an 8A neutral is listed in the model as 3-phase, 4CU)
3. Regulators and capacitors listed in wrong place electrically.

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The “Solution”



Review your “Mission Statement”

1. Keep the lights on as much of the time as possible (ie, during the Super Bowl, soap operas, cooperative board meetings, cooperative annual meetings, presidential debates, election coverage).

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The “Solution” (continued)



2. Quantify the problem by making a list of all known system deficiencies in the slow-growth area.
3. Estimate cost to repair / replace each item based upon current costs.

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The “Solution” (continued)

4. Prioritize the list based upon one or more of the following subjective criteria using good engineering judgment:
 - a) Cost benefit ratio
 - b) Outage reduction
 - c) Improved losses
 - d) Reduced liability
 - e) Improved operational flexibility
 - f) Improved safety

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The “Solution” (continued)

Examine with your current work plan:

- Quantify proposed investment in slow-growth areas.
- Examine Form 7 (year-end) and completed work orders; determine how much investment in slow-growth areas was added to plant over last year.
- Compare these two numbers to see how “big” the problem is. If the amount spent in low-growth areas last year is zero (\$0.00) or essentially zero, you have a huge problem.

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The “Solution” (continued)

How many poles do you have on your system?

- Roughly 20 poles/mile x miles of line = number of poles on the system.
- Review your CPR records of poles. How do they compare?
- How many poles did you inspect last year?

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The “Solution” (continued)

- What is the average age of the poles on your system? By substation? By geographic area? Don't know? You need to find out!
- How many years will it take to get over your system at last year's inspection rate?
5 years? 10 years? 20 years? Never?
- Is the above timeframe acceptable?

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The “Solution” (continued)

- How many poles did you replace last year?
- How many did you inspect and treat with a ground line treatment if needed?
- Determine cost/benefit or payback period on treating poles.

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The “Solution” (continued)

- How many miles of copper/copperweld line do you have left? Check both your CPR records and your engineering model. Most copper line is at least 50 years old!
- Remove steel lines immediately!

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The “Solution” (continued)

- Do you have a plan for removing the copper/copperweld line? What is it? Has the Manager/CEO approved it? What about the Board? Time frame? 5 years? 10 years? Longer?
- Put a portion in each “Work Plan” and follow through on removing it. My recommendation is to replace all small 1-phase or V-phase copper distribution lines within the next 10 years (or less).

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How do you balance capital needs?

1. Examine your current “Work Plan”.
2. What % of the total dollars in the “Work Plan” are directed toward aging plant problems?
3. In a “Work Plan”, the only thing typically addressed is pole replacement.
4. After you have quantified the extent of the problem, you can determine the timeframe in which remedies have to be made and, therefore, how much capital needs to be aimed toward this project on a yearly basis.

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How do you balance capital needs?



Compare new investment dollars per consumer in the various areas of the system or by substation.

Depending upon the age and condition of your system, do not be surprised to find that 10% to 30% of your total distribution yearly budget should be earmarked for aging plant problems.

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In Summary



1. Quantify your system's problems.
All systems vary.
2. Develop or list all known problems.
Update this list yearly.
3. Quantify the remedies in dollars,
man-hours, etc.

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In Summary (continued)



4. Prioritize the remedies based upon the criteria we have discussed during this presentation.
5. Budget funds for the highest priority items.
6. Construct the facilities as planned.
7. Update the “List” and re-prioritize and re-budget yearly.